## SHORT COMMUNICATIONS

*J. Raptor Res.* 38(1):69–77


# CONTAMINANT LEVELS, EGGSHELL THINNING, AND PRODUCTIVITY IN SHARP-SHINNED HAWKS IN FUNDY NATIONAL PARK, NEW BRUNSWICK

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KEY WORDS: *Sharp-shinned Hawk;* Accipiter striatus; *contaminants; diet; Fundy National Park; New Brunswick; population declines.*

Many raptor populations were affected detrimentally by organochlorine (OC) pesticides in Europe and North America during the DDT Era (1946–72) and the evidence for this is both compelling and substantial (e.g., Newton 1979, Risebrough 1986). However, it is now widely assumed that OCs are currently having little impact on raptors, except at the local level (Steidl et al. 1991, Jarman et al. 1996), largely because of the recovery of many populations (e.g., Peregrine Falcon [*Falco peregrinus*]; Cade et al. 1988) and restrictions in use of persistent OCs. Recently, toxicologists have focused more on the carbamate and organophosphorus pesticides, implicated in widespread and direct kills of raptors (e.g., Swainson's Hawk [*Buteo swainsoni*], Goldstein et al. 1996, Mineau et al. 1999). Yet many raptors and other avian species are still showing signs of contamination by OCs, and these chemicals, together with other stress factors, may continue to reduce productivity in some populations (Elliott et al. 1996a, 1996b, Johnstone et al. 1996, Dykstra et al. 1998, Elliott and Norstrom 1998).

Dramatic declines in Eurasian Sparrowhawk (*Accipiter nisus*) populations in Britain and elsewhere in Europe, coincident with the widespread use of DDT and the acutely toxic cyclodiene insecticides, and subsequent recovery following the restrictions in use of these chemicals, have been documented (Newton et al. 1986, Newton and Wyllie 1992). The Eurasian Sparrowhawk's ecological equivalent in the New World, the Sharp-shinned Hawk (*Accipiter striatus*), also declined during the era of the most intensive North American use of DDT (1946–72; Snyder et al. 1973, Kirk 1997, Kirk and Hyslop 1998), following which populations increased (Bednarz et al 1990, Bildstein and Meyer 2000). From 1985 to the mid-1990s, Sharp-shinned Hawk numbers declined at traditional migration count sites (hawk watches) in eastern North America, but not in the Midwest and West (Laura 1992, Kellogg 1993a, Kerlinger 1993, Viverette et al 1996, Wood et. al. 1996).

One explanation for the declining counts of Sharp-shinned Hawks that occurred at eastern migration sites is reproductive impairment caused by contaminants (Duncan 1996, Viverette et al. 1996, Bildstein and Meyer 2000). Another is that migratory "short-stopping" (i.e., individuals not completing their traditional migratory route) has resulted in decreased counts; supporting this, Christmas Bird Count data shows an increase in numbers of hawks overwintering in areas north of the hawkwatch sites (Duncan 1996, Viverette et al. 1996).

Wood et al. (1996) stressed the importance of concurrent research on contaminant levels and productivity in Sharp-shinned Hawks. Results of analyses of tissues opportunistically collected from Fundy National Park, New Brunswick, during nesting studies from 1979–81 (Meyer 1987) and 1983–87 (Woodley and Meyer 1991) suggested contaminant stress. Many eggs failed to hatch at study nests and chemical analysis revealed that some birds may have had sufficiently elevated concentrations of organochlorines to cause breeding failure. As well, productivity appeared to be impaired compared to studies in other regions. During 1990 and 1991, we systematically collect-

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ed eggs and blood samples from nesting adult Sharp-shinned Hawks and recently fledged young to determine whether organochlorines could contribute to low productivity. Specifically, we ask: (1) Are OC concentrations in eggs at levels that have been documented to cause reproductive failure in other raptor species? (2) Are contaminant levels in body tissues at levels associated with mortality or sufficient to cause reproductive failure? (3) Are there age class differences in contaminant concentrations suggesting age-dependent accumulation of contaminants over time?

## METHODS

We conducted this study in 1979–91 in Albert County, New Brunswick (45°30′N, 65°00′W). This is in the Acadian forest region, composed of a mixture of boreal forest and southern deciduous forest types (Burzynski et al. 1986). As a result of forest harvesting (1825–1948), cyclical infestations of spruce budworm (*Choristoneura fumiferana*), and old-field succession following abandonment by farmers, there are a wide variety of habitat types. Conifer-dominated mixedwoods comprise 30% of all forest types; the main tree species being red spruce (*Picea rubens*), black spruce (*P. mariana*), balsam fir (*Abies balsamea*), yellow birch (*Betula alleghaniensis*), white birch (*B. papyrifera*), red maple (*Acer rubrum*) and sugar maple (*A. saccharum*); (Burzynski et al. 1986). This region provides suitable habitat for Sharp-shinned Hawks.

Consistent with observations elsewhere in Canada, all nests were in forest stands dominated by coniferous trees (Meyer 1987). We found occupied nests mainly by searching for plucking sites (Meyer 1987). We studied 16 Sharp-shinned Hawk nests, all found during the period 1979–91. Of these, 12 were in Fundy National Park and the remainder nearby.

**Productivity.** We assessed productivity as the mean number of offspring fledged per nest with eggs, or the mean number fledged per successful nest (a nest in which at least one young was fledged). Both measures were contingent on observing nests until the offspring left.

**Egg Contents.** Between 1979 and 1984 we collected from nests any unhatched eggs for chemical analysis, whereas in 1990–91 we removed one freshly-laid egg randomly from the clutch. We also removed eggshells from nests to analyze contaminant levels in eggshell membranes.

We used calipers to measure egg dimensions and measured eggshell thickness using a Starrett 1010 micrometer (±0.001 mm; (L.S. Starrett Company, Athol, MA). Egg contents were placed in acetone-washed glass containers, and frozen until transported to the National Wildlife Research Centre, (then in Hull, Québec) for chemical analysis. Eggshells were air-dried for at least 2 wk, and then weighed using a triple-beam balance (±0.01 g).

We determined shell thickness indices using the formula developed by Ratcliffe (1967): egg shell mass (mg)/length × breadth (mm). We then calculated percent thinning by comparing this with the pre-1947 thickness index in eggs from southern Canada (mean Ratcliffe thickness index 1.31 ± 0.01 95% CL, $N = 568$; Anderson and Hickey 1972). Ratcliffe indices were derived from one egg per nest; where there were two eggs, the mean was taken.

**Blood Plasma Levels.** We sampled blood plasma levels in adult and young hawks at five nests during the breeding seasons (July–August) of 1988, 1990, and 1991. We caught adults using noose carpets on plucking stumps or with Dho gaza nets and a stuffed Great Horned Owl (*Bubo virginianus*) as a decoy. We caught recently-fledged young with bal chatri traps and used live House Sparrows (*Passer domesticus*) as bait. We extracted one milliliter of blood from the brachial vein of each bird, using a 3 ml disposable syringe containing heparin and 26 gauge needle. Blood samples were centrifuged and the plasma stored frozen until analysis.

**Residues in Liver Samples.** Between 1985 and 1990, we collected 24 hawks killed by collisions with vehicles or windows (New Brunswick, 10; Nova Scotia, 7; Newfoundland, 6; and Prince Edward Island, 1). Hawks were frozen until contaminant analyses were performed; only livers were analyzed for contaminants. Most dead hawks were collected in 1987 (12), followed by 1988 (5), 1986 (4), 1990 (2), and 1985 (1). We classified dead hawks by age and the date they were found: an immature hawk found dead up to 31 December of its first calendar year of life was considered a hatch-year (HY) bird, an immature hawk found dead from 1 January onwards was a second-year (SY) bird, and any adult birds were classed as after second-year (ASY; Canadian Wildlife Service 1977). HY and SY hawks were aged more precisely using 1 July as the mean hatching date in the study area. Carcasses were thawed, livers removed, and standard protocols used for analyses (Peakall et al. 1986).

**Contaminant Analyses.** Apart from analyses conducted prior to 1984 (by the Ontario Research Foundation), all contaminant analyses were performed at the National Wildlife Research Centre. Standard and strict protocols were used for both laboratories (pre- and post-1984) as described by Peakall et al. (1986). All contaminant concentrations are reported on a wet weight basis; we did not correct for water loss because water content for all eggs was >70%. The detection limit for residues was 0.001 mg/kg.

PCB concentrations are reported as the sum of 41 congeners. Prior to 1988, the sum of PCB congeners was expressed as the 1:1 ratio of Aroclor 1254:1260 (Norstrom 1988). To convert Aroclor 1:1 values to the sum of PCBs, we used a conversion factor based on large numbers of specimens for which Aroclor ratios and total summed PCB congeners were available (Turle et al. 1991). We acknowledge some biases in this technique due to site and species variability.

**Diet.** To investigate where hawks may be obtaining contaminants, we collected prey remains at plucking posts and nests in 10 territories. We identified prey using a reference collection of beaks, legs, feet, wings, and feathers and by comparison with specimens in the New Brunswick Museum, Saint John, New Brunswick. We classified prey as Neotropical migrants (wintering mainly south of the United States-Mexico border), short-distance migrants (wintering principally in the continental United States), irruptive migrants (which move periodically and nomadically in response to fluctuations in food supply), or year-round residents based on Canadian Wildlife Ser-

Table 1. Organochlorine and PCB residues (mg/kg wet weight) in Sharp-shinned Hawk eggs collected from Fundy National Park, New Brunswick, in 1979–83 and 1990–91.

| | 1979–83 ($N$ = 2) | | 1990–91 ($N$ = 7) | | |
|---|---|---|---|---|---|
| Compound | Mean[a,b] | Minimum and Maximum | Mean | 95% CL | Minimum and Maximum |
| DDE | 7.53 | 6.2–9.1 | 7.33 | 2.69–20.00 | 1.44–98.08 |
| DDT | 0.07 | 0.06–0.09 | 0.04 | 0.02–0.10 | 0.01–0.43 |
| DDD | 0.09 | 0.09–0.09 | 0.08 | 0.04–0.19 | 0.02–1.36 |
| Mirex | 0.31 | 0.31–0.32 | 0.19 | 0.08–0.43 | 0.06–1.76 |
| *p*-Mirex | ND[c] | ND[c] | 0.01 | 0.04–<0.01 | ND–0.20 |
| Oxychlordane | 0.78 | 0.72–0.85 | 0.28 | 0.18–0.45 | 0.10–0.54 |
| *Trans*-nonachlor | 0.07 | 0.07–0.07 | 0.26 | 0.20–0.49 | 0.06–0.74 |
| *cis*-nonachlor | ND | ND | 0.02 | 0.01–0.06 | 0.04–0.10 |
| Heptachlor epoxide | 0.33 | 0.30–0.37 | 0.13 | 0.08–0.23 | 0.04–0.36 |
| Dieldrin | 0.50 | 0.39–0.64 | 0.13 | 0.02–0.89 | ND–0.94 |
| HCB | ND | ND | 0.01 | 0.01–0.02 | 0.01–0.02 |
| Sum PCBs | 1.52 | 1.42–1.63 | 1.10 | 0.71–1.70 | 0.50–2.49 |
| Percent $H_2O$ | 77.8 | 77.4–78.9 | 83.1 ± 0.52 (SE) | | 81.9–86.0 |
| Percent lipid | 6.7 | 6.1–7.3 | 5.0 ± 0.54 (SE) | | 3.2–7.3 |

[a] Mean of two eggs from the same nest.
[b] Means are geometric, except for $H_2O$ and percent lipid where they are arithmetic.
[c] ND = not detected, i.e., <0.001 mg/kg wet weight.

vice and Breeding Bird Survey (BBS) databases (C. Downes pers. comm.).

**Hypotheses and Statistical Analyses.** Because we obtained blood plasma opportunistically from adult or young hawks from the same nests, we could not compare age classes or sexes statistically because the data were not independent. However, we hypothesized that contaminant levels in livers would differ according to age class, sex, and geographical location. Specifically, we predicted that: (1) contaminant levels in livers of HY or SY hawks should be lower than in ASY hawks, which had greater exposure both temporally and geographically, and (2) contaminant levels in livers of female hawks should differ from those of males because females excrete lipophilic contaminants in their eggs. To test these relationships, we used ANOVA or paired tests. Because starving birds have metabolized the fat where contaminants bioaccumulate, they should have higher contaminant burdens in their livers than those in good condition. Therefore, to compare contaminant levels in liver tissues among age classes we used an analysis of covariance (ANCOVA), with percent fat as a covariate. Finally, to test whether any geographical differences existed in contaminant levels, we examined the effects of latitude and longitude (converted to decimal degrees) as predictors in a multiple linear regression (both latitude and longitude have been shown to affect contaminant levels; e.g., DeWeese et al. 1986).

Because contaminant data were highly skewed, they were log-transformed. All contaminant means are presented as geometric means with 95% confidence limits unless otherwise stated (Newton and Wyllie 1992, Elliott and Martin 1994). We performed statistical analyses using SAS (SAS Instit. 1990). Sample sizes in this paper vary greatly for different contaminant tissue analyses, and it was not possible to collect single eggs, or catch adults or young from every nest. Statistical significance was accepted at $P < 0.05$.

## Results

**Productivity.** Mean clutch size was lower in 1979–83 (2.8 ± SE 0.6) than in 1990–91 (4.1 ± 0.1). Similarly, mean productivity (the number of young fledged from nests with eggs) was lower in 1979–83 (1.3 ± 0.9) than 1990–91 (2.3 ± 0.6). From the nests where hatch frequencies could be determined, a mean of 1.3 ± 0.3 eggs per nest ($N$ = 4) did not hatch in 1979–83, whereas in the 1990s no nest had unhatched eggs ($N$ = 7). Two nests that failed to produce young in the 1990s had some of the highest shell-thinning indices; however, fledging success was 75% at two other nests with high Ratcliffe indices.

**Egg Contents.** We found measurable concentrations of 12 commonly reported organochlorine compounds in egg lipid contents (Table 1). Of these, by far the most prevalent was DDE, followed by the sum of PCBs and oxychlordane. One of two eggs collected from nests in the 1980s had DDE levels of 9.12 mg/kg. Although only two of seven eggs exceeded 10 mg/kg in the 1990s, one had extremely high concentrations, 98.08 mg/kg (Ratcliffe index = 13.7%) and the other held 12.84 mg/kg (Ratcliffe index = 18.3%); an additional egg approached the threshold (7.97 mg/kg). Dieldrin levels did not exceed the level of acute toxicity (1 mg/kg), but one egg in the 1980s contained 0.64 mg/kg and two eggs in the

1990s contained 0.94 and 0.67 mg/kg, respectively. Levels of other cyclodienes did not approach levels of acute toxicity (e.g., heptachlor 1.50 mg/kg) and are therefore not reported. Ratcliffe indices (all from 1990/1991) varied from 5.3–18.3% ($N$ = 7) below the pre-DDT norm; only one egg had thinning in excess of 15%, the overall mean thinning was 11%.

**Blood Plasma Levels.** Blood plasma residue levels were much lower than in egg contents as expected. However, the relative concentrations for different compounds showed a similar ranking in plasma to that in egg lipid. Mean concentrations of contaminants were higher in adult males (e.g., DDE 1.40, range = 0.53–2.65, $N$ = 3) than adult females (0.08, 0.01–0.69, $N$ = 2) in 11 of 12 compounds. In the only case where a direct comparison could be made at the same nest, the adult male had higher blood plasma levels for 9/12 contaminants (the adult female had higher levels of mirex, *trans*-nonachlor, and DDD). Concentrations were also higher in adult males than nestling (e.g., $\bar{x}$ DDE for nestling males 0.04, 0.02–0 08, $N$ = 3; $\bar{x}$ PCBs adult males = 0.69, 0.40–1.75; $\bar{x}$ PCBs nestling males = 0.01, 0.01–0.03), and higher in adult females than nestling ($\bar{x}$ DDE for nestling females 0.03, 0.01–0.14).

**Residues in Liver Samples.** Residue levels in livers were highly variable, with few discernible patterns in relation to age or gender (Table 2). No significant differences existed among age classes according to ANCOVA (no analyses were performed for DDD and *p*-mirex, because too few specimens contained these chemicals in the HY and SY age classes). Only 1/5 HY and 1/7 SY hawks contained measurable levels of *p*-mirex, and only 2/5 HY and 1/7 SY hawks contained DDT. No significant difference was found in DDE levels among age classes. Comparing adults and immatures (HY and SY combined), irrespective of gender, indicated only one significant difference (for *trans*-nonachlor; Mann Whitney $U$-test $Z$ = 2.452, $P$ = 0.01). The multiple regression analysis indicated that there was no effect of latitude or longitude on levels of any contaminant in livers of hawks.

**Prey Remains.** Sharp-shinned Hawks preyed on 24 species of birds: 13 Neotropical migrants, 7 short-distance migrants, and 4 resident or irruptive species (Table 3). No significant difference was found in the proportion of Neotropical compared with short-distance migrant prey species ($\chi^2$ = 0.259, $P$ > 0.1) or between the proportion that were Neotropical rather than resident species ($\chi^2$ = 2.436, $P$ > 0.05). Prey ranged in size from a Golden-crowned Kinglet (*Regulus satrapa*) to a Ruffed Grouse (*Bonasa umbellus*); all prey with a mass >28 g were likely killed by female Sharp-shinned Hawks. Numerically, Neotropical migrants comprised 38.6%, short-distance migrants 34.8%, and resident or irruptive species 3.7%. However, by mass, short-distance migrants were most important (57.9%), followed by Neotropical migrants (23.5%), and lastly resident and irruptive species (18.1%). The most important species by number was American Redstart (*Setophaga ruticilla*), followed by American Robin (*Turdus migratorius*), Tennessee Warbler (*Vermivora peregrina*), and White-throated Sparrow (*Zonotrichia albicollis*; Table 3). American Robin contributed most by mass, followed by Ruffed Grouse ($N$ = 1), White-throated Sparrow, and Hermit Thrush (*Catharus guttatus*; Table 3).

## DISCUSSION

Our results demonstrate that Sharp-shinned Hawks in Fundy National Park were contaminated by several organochlorine compounds in the period 1983–91. Not surprisingly, given its persistence and the extent to which it was used, DDE was, by far, the most important. Levels of some other pesticides (e.g., dieldrin) also were moderately high as well.

Were the levels found in our study high enough to cause impaired reproduction? Several eggs in our study contained close to the critical level of 10 mg/kg DDE (Noble et al. 1993 for summaries of critical levels) and one had 98 mg/kg DDE. Contaminant levels in eggs from Fundy National Park were apparently higher than those in southern Ontario (Elliott and Martin 1994) for seven of eight chemicals detected in 1979–83 and five of 12 in 1990–91, although our very small sample sizes limit this comparison.

The blood plasma data suggested that adults had higher contaminant burdens than young, as in other raptors (Bogan and Newton 1977, Henny and Meeker 1981). Adult males also had higher contaminant levels than adult females, perhaps because females could deposit contaminants in their eggs or because they foraged in different habitats and ate different-sized prey (Bildstein and Meyer 2000). For example, males are more likely to prey on small Neotropical migrant Parulidae than are females (Meyer 1987); and these migrants may have higher contaminant loads as a result of spending the boreal winter in Latin America. Plasma contaminant concentrations in adult males were also higher than those reported by Elliott and Shutt (1993).

Where are Sharp-shinned Hawks in Fundy National Park obtaining these contaminants? Several researchers have proposed that hawks accumulate contaminants from prey while spending the nonbreeding season in Central and South America (Elliott and Shutt 1993, Elliott and Martin 1994), as in the Peregrine Falcon (e.g., Johnstone et al. 1996). However, band recoveries from Cape May, NJ and Hawk Mountain, PA demonstrate that hawks breeding in eastern Canada winter in the Atlantic plain of the southeastern United States, and peninsular Florida (Clark 1985, Viverette et al. 1996), whereas hawks migrating through Great Lakes banding stations winter mostly west of the Appalachians and as far south as Central America (Duncan 1985, Evans and Rosenfield 1985, Carpenter et al. 1990).

We propose that Sharp-shinned Hawks in Fundy National Park are accumulating contaminants both from

Table 2. Organochlorine and PCB residue levels (mg/kg) in livers of Sharp-shinned Hawks found dead in Atlantic provinces between 1985–90. Numbers show geometric means with range in parentheses.

| | Hatch-year | Second-year | | Immatures[a] (N) | After second-year | | Adults[b] (N) |
|---|---|---|---|---|---|---|---|
| Compound | Female (N) | Male (N) | Female (N) | | Male (N) | Female (N) | |
| DDE | 1.97 (5) | 1.03 (3) | 4.32 (4) | 2.15 (12) | 3.82 (5) | 1.76 (4) | 2.70 (9) |
| | (0.42–7.58) | (0.77–1.24) | (1.62–17.31) | (0.42–17.31) | (1.79–7.97) | (0.84–3.63) | (0.84–7.97) |
| DDT | <0.01 (2) | ND[c] | <0.01 (1) | <0.01 (3) | <0.01 (3) | <0.01 (3) | <0.01 (6) |
| | (ND–0.02) | | (ND–0.06) | (ND–0.06) | (ND–0.01) | (ND–<0.01) | (ND–0.01) |
| DDD | 0.03 (5) | <0.01 (3) | 0.08 (4) | 0.03 (12) | 0.01 (5) | 0.01 (4) | 0.01 (9) |
| | (0.01–0.07) | (<0.01–<0.01) | (0.02–0.78) | (<0.01–0.78) | (<0.01–0.05) | (0.01–0.02) | (<0.01–0.05) |
| Mirex | 0.05 (5) | 0.03 (3) | 0.06 (4) | 0.05 (12) | 0.17 (5) | 0.07 (4) | 0.11 (9) |
| | (<0.01–0.22) | (0.02–0.03) | (0.02–0.34) | (<0.01–0.34) | (0.10–0.29) | (0.04–0.12) | (0.04–0.29) |
| *p*-Mirex | <0.01 (1) | ND | <0.01 (1) | <0.01 (2) | 0.02 (4) | 0.01 (4) | 0.01 (8) |
| | (ND–0.02) | | (ND–0.05) | (ND–0.05) | (ND–0.06) | (0.01–0.02) | (ND–0.06) |
| Oxychlordane | 0.09 (5) | 0.06 (3) | 0.13 (4) | 0.09 (12) | 0.13 | 0.07 (4) | 0.10 (9) |
| | (0.03–0.45) | (0.04–0.10) | (0.05–0.50) | (0.03–0.50) | (0.05–0.23) | (0.04–0.11) | 0.04–0.23) |
| *trans*-nonachlor | 0.03 (5) | 0.03 (3) | 0.02 (4) | 0.02 (12) | <0.01 (5) | <0.01 (3) | <0.01 (8) |
| | (<0.01–0.16) | (0.02–0.05) | (<0.01–0.48) | (<0.01–0.48) | (<0.001–0.01) | (ND–0.05) | (ND–0.05) |
| *cis*-nonachlor | | | | | | | |
| | 0.01 (5) | 0.01 (3) | 0.02 (4) | 0.01 (12) | 0.03 (5) | 0.01 (4) | 0.02 (9) |
| Heptachlor epoxide | (<0.01–0.05) | (<0.01–0.01) | (<0.01–0.09) | (<0.01–0.09) | (0.01–0.04) | (<0.01-0.02) | (<0.01–0.04) |
| | <0.01 (2) | ND | <0.01 (2) | <0.01 (4) | ND | 0.01 (3) | <0.01 (3) |
| Dieldrin | 0.02–0.09 | | (ND–0.59) | (ND–0.59) | | (ND–0.08) | (ND–0.08) |
| | 0.02 (5) | 0.03 (3) | 0.03 (4) | 0.03 (12) | 0.02 (5) | 0.02 (4) | 0.02 (9) |
| | (<0.01–0.12) | (<0.01–0.14) | (<0.01–0.11) | (<0.01–0.14) | (<0.01–0.08) | (<0.01–0.06) | (<0.01–0.08) |
| HCB | 0.02 (5) | 0.03 (3) | 0.02 (4) | 0.02 (12) | 0.03 (5) | 0.01 (4) | 0.02 (9) |
| | (<0.01–0.21) | (0.02–0.06) | (0.01–0.03) | (<0.01–0.21) | (0.01–0.07) | (0.01–0.02) | (0.01–0.07) |
| Total PCBs | 0.55 (5) | 0.50 (3) | 0.71 (4) | 0.58 (12) | 1.55 (5) | 0.38 (4) | 0.83 (9) |
| | (0.12–3.51) | (0.34–0.95) | (0.28–1.74) | (0.12–3.51) | (0.73–3.33) | (0.32–0.53) | (0.32–3.33) |
| Percent Lipid | 3.43 ± 0.51 | 2.21 ± 0.56 | 3.63 ± 0.17 | 3.19 ± 0.29 | 4.19 ± 0.59 | 4.19 ± 0.97 | 4.19 ± 0.50 |
| | (2.0–4.88) | (1.12–3.00) | (3.14–3.96) | (1.12–4.88) | (3.29–6.43) | (2.30–5.94) | (2.30–6.43) |

[a] Immature = hatch year and second year birds.
[b] Adults = after second year birds.
[c] ND = no data.

Table 3. Frequency of occurrence and percent biomass of prey items identified in 10 Sharp-shinned Hawk territories in the Bay of Fundy National Park, New Brunswick, study area.

| PREY SPECIES | NUMBER | PERCENT BY NUMBER | PERCENT BY MASS (mass in g)[a] |
|---|---|---|---|
| Neotropical migrants | | | |
| Yellow-bellied Flycatcher (*Empidonax flaviventris*) | 1 | 0.5 | 0.3 (11.6) |
| Swainson's Thrush (*Catharus ustulatus*) | 3 | 1.6 | 2.4 (32.7) |
| Gray Catbird (*Dumetella carolinensis*) | 1 | 0.5 | 0.9 (37.2) |
| Red-eyed Vireo (*Vireo olivaceus*) | 3 | 1.6 | 1.4 (18.9) |
| Tennessee Warbler (*Vermivora peregrina*) | 15 | 7.9 | 4.8 (12.9) |
| Magnolia Warbler (*Dendroica magnolia*) | 6 | 3.2 | 1.4 (9.6) |
| Cape May Warbler (*D. tigrina*) | 3 | 1.6 | 0.8 (11.0) |
| Black-throated Green Warbler (*D. virens*) | 3 | 1.6 | 0.7 (8.8) |
| Blackburnian Warbler (*D. fusca*) | 9 | 4.8 | 2.2 (9.8) |
| Bay-breasted Warbler (*D. castanea*) | 3 | 1.6 | 0.4 (15.0) |
| American Redstart (*Setophaga ruticilla*) | 21 | 11.1 | 4.7 (9.1) |
| Ovenbird (*Seiurus aurocapillus*) | 4 | 2.1 | 2.2 (22.7) |
| Rose-breasted Grosbeak (*Pheucticus ludovicianus*) | 1 | 0.5 | 1.1 (45.6) |
| Short-distance migrants | | | |
| Winter Wren (*Troglodytes troglodytes*) | 5 | 2.6 | 1.1 (8.9) |
| Golden-crowned Kinglet (*Regulus satrapa*) | 1 | 0.5 | 0.2 (6.2) |
| Hermit Thrush (*Catharus guttatus*) | 10 | 5.3 | 7.2 (29.1) |
| American Robin (*Turdus migratorius*) | 18 | 9.5 | 34.4 (77.3) |
| Yellow-rumped Warbler (*Dendroica coronata*) | 10 | 5.3 | 3.0 (11.9) |
| White-throated Sparrow (*Zonotrichia albicollis*) | 14 | 7.4 | 8.3 (23.8) |
| Dark-eyed Junco (*Junco hyemalis*) | 8 | 4.2 | 3.9 (19.6) |
| Irruptive species | | | |
| Evening Grosbeak (*Coccothraustes vespertinus*) | 1 | 0.5 | 1.3 (54.0) |
| Year-round residents | | | |
| Ruffed Grouse (*Bonasa umbellus*) | 1 | 0.5 | 14.2 (576.5) |
| Downy Woodpecker (*Picoides pubescens*) | 3 | 1.6 | 2.0 (27.0) |
| Boreal Chickadee (*Poecile hudsonicus*) | 2 | 1.1 | 0.5 (9.8) |
| Unidentified warbler | 27 | 14.3 | |
| Unidentified sparrow | 14 | 7.4 | |
| Mammals | | | |
| Red-backed Vole (*Clethrionomys gapperi*) | 1 | 0.5 | 0.6 (24.0)[b] |

[a] Masses (g) are from Dunning (1993); where male and female masses were given separately a mean was taken.
[b] Mass taken was average of range given by Banfield (1974).

their breeding grounds, and their wintering areas in the southern United States. DDT use was once widespread in North America, and low-level use continues in Mexico, Central and South America (UNEP 2002). Interestingly, New Brunswick forests were subjected to probably the longest and most intensive aerial pesticide spraying program in the world in order to control outbreaks of spruce budworm (Environment Canada 1989). Between 1952 and 1990, 100 000 mt (220 million pounds) of DDT and Fenitrothion were applied and a total of 19.392 million ha were sprayed between 1975 and 1986 (Environment Canada 1991). Thus, Sharp-shinned Hawks and their prey could be accumulating contaminants from multiple sources.

Unfortunately, we lack data on contaminant levels in prey species of Sharp-shinned Hawks in Fundy National Park. Neotropical migrant songbirds were the most important prey identified in this study. Migrant songbirds have been documented to be contaminated by several OC pesticides (Mora and Anderson 1991, Harper et al. 1996) and DDE levels were generally higher in these species than short-distance migrants or residents (DeWeese et al. 1986). Five of the species preyed on by hawks in Fundy were shown to contain detectable OC residues (at the ng/g level) by Harper et al. (1996), including Gray Catbirds (*Dumetella carolinensis*), Swainson's Thrushes (*Catharus ustulatus*), Red-eyed Vireos (*Vireo olivaceus*), Bay-breasted Warblers (*Dendroica castanea*), and American Redstarts (*Setophaga ruticilla*). Moreover, American Robins, by far the most important prey item by mass of Sharp-shinned Hawks in our study, have been found to contain extremely high levels of DDE at "hot spots," particularly orchards, elsewhere in Canada (e.g., Elliott et al. 1994, Hebert et al. 1994).

Given our small sample sizes it is difficult to say whether contaminants are having an adverse effect on Sharp-shinned Hawk populations in our study area, or in the Atlantic region generally. However, eggshell thinning in this study was sufficient to cause reproductive failure in at least three of nine (33%) nests. In the Eurasian Sparrowhawk, DDE levels of 62–104 ppm (lipid weight basis) caused shell-thinning of 11–20% and a corresponding population reduction of 14–35%. Productivity in this species was reduced by 14% at 8% thinning and 32% at 20% thinning (Newton et al. 1986). Thus, contaminants merit serious attention by researchers as a possible contributory factor in eastern Sharp-shinned Hawk declines.

RESUMEN.—Entre 1979 y 1984, los gavilanes (*Accipiter striatus*) del Parque Nacional Fundy (New Brunswick) tuvieron un éxito reproductivo bajo en comparación con cualquier otra parte de Norteamérica. Examinamos los parámetros reproductivos de 16 nidos entre 1979 y 1991. Colectamos huevos sin eclosionar, seleccionando aleatoreamente un solo huevo, tomamos muestras de sangre de gavilanes adultos y jóvenes, al igual que muestras de sangre e hígado de la mayoría de los azores muertos en época no reproductiva para analizar sus contaminantes. El adelgazamiento del cascaron varió de 5.3–18.3% bajo la norma anterior a 1947, el rango superior fue mas grande que el nivel mínimo de 15% en el cual fracasan en su intento reproductivo otras poblaciones de aves rapaces. Los huevos contuvieron cantidades detectables de residuos de 12 contaminantes comúnmente analizados; el DDE fue el mas abundante seguido por los bifenilos policlorados (PCBs). No se encontraron diferencias geográficas en el nivel de contaminantes en los hígados de los azores muertos, no hubo diferencias entre las clases de edad o sexo. Encontramos 24 especies de presas en la dieta de 10 nidos de los azores; los emigrantes neotropicales fueron los mas importantes en número, seguidos por los emigrantes de distancias cortas.

[Traducción de César Márquez]

ACKNOWLEDGMENTS

K. Meyer's work from 1979–84 was supported in part by grants from The Frank M. Chapman Memorial Fund, Sigma Xi, and the University of North Carolina, Chapel Hill. Numerous persons provided help with this project; K. Wilson was critical as field assistant and arranged for identification of feathers from prey items; F. Lane provided veterinary advice and trapping assistance. We thank M. Burzynski, D. Christie, H. Deichmann, K. East, B. Forsythe, B. Harvey, F. Lane, G. Mercer, G. Sinclair, S. Sinclair, R. Walker, and D. West for helping to find nests or other information. We thank the team who analyzed contaminants at the Ontario Research Foundation and the Canadian Wildlife Service, and in particular M. Kassera and H. Won, as well as G. Fox, S. Jones, and S. Kennedy for help with computing facilities. Keith L. Bildstein, J. L. Shutt, and four anonymous reviewers provided extremely valuable comments on earlier drafts of the manuscript.

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Received 23 April 2003; accepted 4 November 2003
Associate Editor: Ian G. Warkentin

*J Raptor Res.* 38(1):77–81


## A RETROSPECTIVE STUDY OF MORTALITY AND REHABILITATION OF RAPTORS IN THE SOUTHEASTERN UNITED STATES

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KEY WORDS: *Injury; mortality factor; raptor; rehabilitation; release.*

Increasing habitat loss and fragmentation create more opportunities for humans and raptors to interact, often negatively affecting the birds. As a result, there is a need for rehabilitation facilities that can receive injured animals, treat wildlife, and release them back into the wild. In this paper we evaluate the effect that humans have on raptors by summarizing records of birds admitted to a raptor rehabilitation center. The records at these centers are valuable sources of data that provide current information on the animals, aspects of their natural history, and conservation.

We examine the following four questions within this paper: (1) are all raptor species equally likely to be released, (2) is the source of injury related to the likelihood for release, (3) do sources of injury differ between

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